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TECHNICAL REPORT NO. 11865

CORRELATION STUDY ON A 1¼-TON TRUCK BETWEEN FIELD TESTS AT ABERDEEN PROVING GROUND AND LABORATORY SIMULATION TEST AT TACOM

FEBRUARY 1974

U.S. ARMY TANK-AUTOMOTIVE COMMAND LABORATORIES

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by Carol D. Rose

TACOM

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CONCEPT AND TECHNOLOGY DIVISION

U.S. ARMY TANK AUTOMOTIVE COMMAND Warren, Michigan

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CORRELATION STUDY ON A 1¼-TON TRUCK BETWEEN FIELD TESTS AT ABERDEEN PROVING GROUND AND LABORATORY SIMULATION TEST AT TACOM

BY

CAROL D. ROSE

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AMCMS CODE 675702.12.14300

TEST MANAGEMENT BRANCH

ABSTRACT

PURPOSE

Determine the degree of correlation of vibration-induced failure incidents between field tests at Aberdeen Proving Ground (APG) and a laboratory simulation test of the 1½ Ton XM705 Truck.

METHOD

Six trucks were field tested at APG. A total of 300,000 test miles were accumulated. An accelerated laboratory simulation test was developed from operating field data recorded on magnetic tape at APG. A 245-hour laboratory vehicle shake test was run on one vehicle. A study was made to determine the degree of correlation between the field tests and the laboratory test.

RESULTS

1. Field tests produced 17 types of failure mode incidents attributed to vibration. The laboratory produced 11 of the same failure mode incidents.

2. Mean miles between incidents in the field tests was 3,571. Mean time between incidents in the laboratory was 15.31 hours.

CONCLUSIONS

1. The laboratory test duplicated 64.7 percent of failure mode incidents attributed to vibration which had occurred in the field.

2. Based on an iso-reliability relationship, one hour of laboratory testing was equivalent to 233.2 miles of field testing.

FOREWORD

This study was conducted under the Engineering Audit Program, DA Project No. 1G765702D063. Funds were authorized under the subtask entitled "Develop Methods For Correlating Laboratory Simulation Testing", CRN RE300144.

Acknowledgment is given to Dr. Leonard R. Lamberson, Wayne State University, Department of Industrial Engineering. Dr. Lamberson was consulted for his expertise in the field of reliability statatistics and he performed most of the computations.

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1. INTRODUCTION

One of the objectives of engineering audit is to develop laboratory tests that simulate as nearly as possible the environment a vehicle or component experiences in the field. A measure of this duplication can be determined by statistical correlation studies between loads, acceleration, torques, and other stresses that a particular component is subjected to in the field and during the laboratory test.

It is usually desirable to accelerate a laboratory test so that vehicles and components can be evaluated in less time and at less cost in the laboratory than in the field. The laboratory vehicle shake test discussed herein was an accelerated test. This was an initial study to determine to what degree the laboratory test duplicated the mode of failure experienced by components on the vehicle in the field. A correlation between miles of field test and hours of laboratory test was also desirable.

2. OBJECTIVE

Determine the degree of correlation between field tests at Aberdeen Proving Ground and laboratory simulation testing of the 1½ ton XM705 Truck.

3. CONCLUSIONS

a. The laboratory test duplicated 64.7 percent of failure mode incidents attributed to vibration which had occurred in field tests.

b. Analyses of the data indicated that one hour of laboratory testing was equivalent to 233.2 miles of field testing for the type of failure mode studied. The total of 245 laboratory hours was thus approximately equivalent to 57,000 miles of field testing.

c. Laboratory tests were more efficient than field tests in identifying shortcomings and deficiencies caused by vibration.

4. PROCEDURE

A 245-hour laboratory simulation vehicle shake test was run on a 1½ ton cargo truck. A table was compiled of deficiencies and shortcomings (incidents) which occurred during the test. A table was also compiled on deficiencies and shortcomings attributed to vibration during field tests at Aberdeen Proving Ground. These tables are presented as original data in Appendix A of the attached report submitted by Dr. Leonard R. Lamberson. Dr. Lamberson is a consultant with expertise in the field of reliability statistics. He was employed to determine what type of analyses could be performed on the data compiled in the tables, and to do the computations. The analyses and results are given in the attached report by Dr. Lamberson.

5. DISCUSSION

During development of the XM705 vehicle, operating field data were obtained on magnetic tape over selected courses at Aberdeen Proving Ground. The recorded data were used to develop a laboratory simulation vehicle shake test using inputs of the axle at each wheel. Using information generated by power spectral density curves and histograms of the field data, selected actions at the axle inputs were simulated in the laboratory. The laboratory test was accelerated by elimination of small accelerations and excursions. Magnitudes of the remaining excursions were also slightly increased to further accelerate the laboratory test. The magnitude of the increase was limited so that the ride was still tolerable to a driver or passenger. One of the objectives of this study was to determine the relationship between test miles at Aberdeen and laboratory test hours.

The XM705 cargo truck was field tested at several locations. For purposes of this study, comparisons were made between the laboratory test and field tests at APG only, since the laboratory test was generated from data recorded at APG. Data on the ambulance version tested at APG was not included. The comparison was between one vehicle tested in the laboratory, and six tested at APG.

A total of 1176 Equipment Performance Reports (EPR's) generated at APG were evaluated to determine those incidents of failure which could be due exclusively to shock and/or vibration. An example of a type of incident not included was the loosening of nuts, washer and rubber cushion which secure the transfer case mounting brackets to the frame cross member. There were ten incidents in the field test when these were loose or missing. This type incident did not occur in the laboratory. It was concluded that in the field test the incident occurred because of torque transmitted through the transfer case, plus an interaction between the torque and vibration, in addition to vibration itself. The engine was not running during the laboratory test; hence, torque was not a factor during the laboratory test.

One conclusion was that one hour of laboratory testing demonstrated the same reliability as 233.2 miles of APG testing. This conclusion must be interpreted to apply only to the types of failures encountered in the laboratory test. Also, the 233.2 equivalent miles is an average for the many types of failures included in this study. That is, the equivalent mileage is different for each type of failure. This can be demonstrated by the abrasion failure of the main leaf of the spring, caused by the second spring leaf wearing a groove in the main leaf. This type of failure occurred ten times at APG but not in the laboratory. The laboratory had larger excursions of the suspension system such that the wear area of the second spring leaf on the main leaf was larger than in the field. Since the test was accelerated the main leaf did not receive as much abrasion over a small stress area from the second leaf in the laboratory test as in the field test.

Analysis of the data showed that the laboratory test duplicated 11 of 17, or 64.7 percent of failure mode incidents attributed to vibration which had occurred in field tests. However, it must be remembered that six vehicles were field tested and only one vehicle was tested in the laboratory. The table entitled "Matrix of Incident Occurrence Per Field Test and Laboratory Test" gives a broader view of the relationship between field and laboratory test failures. Of the 17 types of incidents which occurred in the field, only one vehicle had as many as eleven of the different types of incidents. The range for the six vehicles was four to eleven, as shown in the table. Additionally, the rule used for this comparison of field test versus laboratory test was that the number of types of incidents was determined from the field tests. Actually there were also 17 different types of incidents which occurred on the one vehicle tested in the laboratory. It was concluded that the laboratory test was more efficient than field tests in identifying shortcomings and deficiencies caused by vibration.

There was some difficulty in determining similarity of incidents between the field and laboratory. There were also individual decisions made on whether a failure, or incident was caused primarily by vibration or shock. It is therefore likely that differences in opinion by individuals would cause analysis of the data to vary somewhat. Results of the analyses must therefore be considered approximate, rather than exact.

MATRIX OF INCIDENT OCCURRENCES PER FIELD TEST AND LABORATORY TEST

Incident Type	Laboratory Test	Field Test Vehicle No 33771	33971	34071	34171	34271	34371
1	X				X		
2	X	X		X	X	X	X
3		X	X	X	X		X
4	X				X		
5					X		
6	X	X	X	X	X	X	
7		X	X	X	X	X	
8	X	X	X	X			
9	X		X				
10	X	X	X	X	X		
11	X		X				
12				X	X		
13		X		X	X	X	X
14	X	X		X	X		
15	X						X
16	X	X					
17							X
TOTALS	11	9	7	9	11	4	5

NOTE: Each "X" indicates the type of incident occurred one or more times.

An Analysis of the Degree of Correlation

Between

Proving Ground and Laboratory Simulated Testing

24 September, 1973

Submitted to

Engineering Audit - Test Management Branch

Concept and Technology Division

Mobility Systems Laboratories

U.S. Army Tank-Automotive Command

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I. INTRODUCTION

The purpose of this study was to establish the degree of correlation from a reliability standpoint for vehicles tested at the Aberdeen Proving Grounds (APG) and for similar vehicles tested in a Laboratory Test Simulator (LAB) at the U.S. Army Tank-Automotive Command. Specifically, data was available for six XM705 1-¼ ton utility trucks tested at APG and for one XM705 tested in the LAB. The results of these tests were used as the data base for this comparison. Throughout this report the word "Incident" will be used to describe a vehicle malfunction which implies unreliability.

A summary of the conclusions immediately follows this section. The summary is based on a statistical comparison of the data base, after this data base was reviewed for similar incidents. The problems in reviewing the data base are discussed in the section entitled "Refinement of the Data Base." The final section includes the basic theory used to develop the degree of correlation between the APG and the LAB.

II. SUMMARY OF THE ANALYSIS

If the APG data is taken as a basis for the incidents that were present in the population of vehicles under test, the LAB test duplicated 64.7% of these incidents one or more times. This percent duplication could be expected to vary from test to test and confidence limits can be placed on the true percent duplication, P. The 90% confidence limits for this percentage are:

$$42.0\% \leq P \leq 83.0\%$$

or one is 90% confident that the true percentage of duplication is in the stated interval.

The relationship between LAB hours and APG miles of testing was first established by considering all incidents. The test data indicate that one hour of LAB testing is equivalent to 233.2 miles of APG testing from a reliability standpoint. Or saying this another way, one hour of LAB testing demonstrates the same reliability as 233.2 miles of APG testing.

Now this 233.2 mile/hour relationship is estimated from limited test results and it is reasonable to consider the accuracy of this ratio. Confidence limits can be used as an indication of accuracy, and in this case, the 81% confidence limits on this ratio are:

$$122. \leq k \leq 428.$$

A further analysis was made by classifying incidents as either catastrophic, major, or minor. The problem in classifying incidents in this manner is that the analyst must exercise judgement as to the categorization of each incident. However, with incidents as categorized in this study, the results follow:

Category	Ratio (k)	81% Confidence Limits
Catastrophic	306.0 mi/hr.	$51.5 \leq k \leq 1371.$
Major	437.3 mi/hr.	$172.9 \leq k \leq 1046.9$
Minor	183.5 mi/hr.	$17.7 \leq k \leq 281.8$

In this study the minimal amount of testing, particularly in the LAB where only one vehicle was tested, produced relatively few incidents. This is reflected in the wide confidence limits. This problem became even more pronounced when incidents were catogorized, because the small number of total incidents were divided among three categories.

III. REFINEMENT OF THE DATA BASE

Before a comparison between the LAB and APG data could be made the data had to be reviewed. During this review some judgements were made. This section will point out the decisions which were made and which resulted in the final set of data for analysis.

Three sets of documents will be referred to in this section. These documents are included in the Appendices and are as follows:

Appendix	Page	Documents
A	13	Original Data
B	25	Incident Matching
C	34	Overall Incident Summary

The original data (Appendix A) has certain incidents which are X'd (X) and these incidents were not included in the study. The exclusion of an incident was done in consultation with TACOM personnel and by carefully reviewing the EPR's. The primary reason for excluding incidents from the APG data was that they were due to the power train operation, and in the LAB the test was for vibration alone without the vehicle's engine or power train in operation. Thus the LAB should not be expected to duplicate torque or heat-related incidents.

The final data set with similar LAB and APG incidents matched up can be found in Appendix B with a brief overall summary included as Appendix C.

The above documents constitute the data base for this analysis. The APG data was generated by six vehicles with two traveling 30,000 miles and four traveling 60,000 miles producing a total of 300,000 vehicle miles. The LAB test was on one vehicle for 245 hours.

IV. DEVELOPMENT OF THE ANALYSIS

This section develops the theoretical procedure used for the basis of comparison. Specific numeric values are calculated for each result.

Simple Incident Comparison

If the APG incidents are taken as a basis for the different types of incidents present, then the following analysis is evident:

Number of Different Incidents Appearing in APG $= 17$[1]

Number of Times APG Incident was Matched at Least Once in LAB $= 11$

Percentage of Time LAB Duplicated APG Incident $100 \times \frac{11}{17} = 64.7\%$

Or a single estimate of the percent duplication is 64.7%. This analysis compares the incidents generated by one LAB vehicle to six APG vehicles. The categories generated by the six APG vehicles are taken as the true population of categories present in the vehicles.

Now if P is the true percentage of matches of LAB to APG then the 90% two-sided confidence limits about P are:[2]

$$42.0\% \leq P \leq 83.0\%$$

Or one can assert with 90% confidence that the true percentage of LAB duplication is from 42.0 to 83.0.

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[1]See Appendix C, page 28

[2]Reliability Handbook: ACMP 702-3, U.S. Army Materiel Command, Washington, D.C., October, 1968.

Relationship Between LAB Test Hours and APG Mileage - Overall Comparison

The overall comparison considers all incidents as being equal in consequences and relates all APG incidents to all LAB incidents. The distribution model used is the exponential, and is given by:

$$f(x) = \frac{1}{\theta} e^{-x/\theta}; \quad x \geq 0, \ \theta > 0$$

where

x = miles between incidents for the APG data

or

x = hours between incidents for the LAB data

and

θ = mean miles between incidents for the APG data (MMBI)

or

θ = mean time between incidents for the LAB data (MTBI)

Also the reliability function is given by:

$$R(x) = e^{-x/\theta}.$$

This analysis assumes a stable failure rate over the duration of the test. This basically means that there was not a significant early failure period, and that wearout did not produce an increasing failure rate during the latter portion of the test.

Then the following analysis is applied:

APG Summary - Overall

Total Number of Incidents = 84

Total Number of Miles = 300,000

MMBI = 3,571

$$R(x) = e^{-x/3571}$$

x = Number of miles

LAB Summary - Overall

Total Number of Incidents = 16

Total Number of Test Hours = 245

MTBI = 15.31

$$R(t) = e^{-t/15.31}$$

t = Hours of test

Now a point estimate of the reliability relationships between the LAB and APG can be approached as follows:

For an iso-reliability relationship,

$$e^{-x/3571 \text{ mi.}} = e^{-t/15.31 \text{ hr.}}$$

$$\frac{x}{3571} = \frac{t}{15.31}$$

or

$$x = \frac{3571}{15.31} t$$

which gives

$$x = 233.2 t$$

This means that one hour of test time is equivalent to 233.2 miles of APG testing. or saying this another way, one hour of LAB testing demonstrates the same reliability as 233.2 miles of APG testing.

Thus a factor k has been developed for the relationship between LAB hours and APG miles. Confidence limits for this factor are approached in the following manner.

The procedure for setting confidence limits on the LAB and APG results are well documented[1] and proceeds as follows:

[1] Bazovsky, Reliability Theory and Practice, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1961, Chapter 22.

LAB $\alpha = .10$

$$\frac{2T}{\chi^2_{\alpha/2,2(r+1)}} \leq MTBI \leq \frac{2T}{\chi^2_{1-\alpha/2,2r}}$$

$r = 16$ $T = 245$ hrs.

$\chi^2_{.05,34} = 48.59$

$\chi^2_{.95,32} = 20.08$

$10.1 \leq MTBI \leq 24.4$

APG $\alpha = .10$

$r = 84$ $T = 300,000$ mi.

$\chi^2_{.05,170} = 201.14$*

$\chi^2_{.95,168} = 138.74$*

$2983 \leq MMBI \leq 4325.$

The confidence limit for the multiplier (k) for the ratio between LAB hours and APG miles is developed as follows:

The confidence limits for the LAB and APG are $10.1 \leq MTBI \leq 24.4$ and $2983 \leq MMBI \leq 4325$ with a confidence coefficient of $\alpha = 0.10$ in each case. The extreme ratio defined by these two limits is $122. \leq k \leq 428$. However, the confidence is not $\alpha = 0.10$ for these limits.

The confidence coefficient is calculated as follows:

Let

A = The event that the LAB limits do not contain the true MTBI.

B = The event that the APG limits do not contain the true MMBI.

Then

$P(A) = P(B) = \alpha = 0.10$

for the LAB and APG confidence limits.

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*Using the approximation $\sqrt{2\chi^2}$ is normal with mean $\sqrt{2v-1}$ and standard deviation of unity, where v is the degrees of freedom.

Now the true value of k will not fall in the calculated interval if either event A or B occurs. Thus,

$$\alpha_k = P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

where α_k is the confidence coefficient for the limits about k. Substituting in the numerical values gives:

$$\alpha_k = 0.19.$$

Or the limits about k are 81% two-sided confidence limits.

Relationship between LAB Test Hours and APG Mileage - Comparison by Category

An attempt was made to categorize incidents according to severity and then to analyze the data by category. There are several problems in doing this and specifically the following are noted:

1. Categorization of events involves some degree of judgement and this can introduce controversy.

2. Since only one LAB vehicle was tested, the total number of failures obtained is small. Subdividing these failures into categories means that there will be a still smaller number of failures per category which will produce wide confidence limits and is indicative of a poor estimator.

The definitions of incident classifications used is as follows:

Catastrophic Event - An event that has a high chance (80% or above)* of causing a mission abort when the vehicle is operating in unimproved gravel terrain with a normal payload.

Major Event - An event that has a moderate chance (40% or above but not high enough to be classified as catastrophic) of causing a mission abort when the vehicle is operating in unimproved gravel terrain with a normal payload.

Minor Event - An event that most likely will not cause a mission abort.

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* As judged by this analyst.

The final incident categorization can be found in Appendix D, page 31. The analysis for each category is identical to the previous procedure and follows:

Catastrophic Incidents

APG

Number of Incidents = 12

MMBI = 25,000

90% Confident Limits

$\chi^2_{.05,26} = 38.885$

$\chi^2_{.95,24} = 13.848$

T = 300,000 mi.

$15{,}430 \leq \text{MMBI} \leq 43{,}328$

LAB

Number of Incidents = 3

MTBI = 81.7

90% Confidence Limits

$\chi^2_{.05,8} = 15.507$

$\chi^2_{.95,6} = 1.635$

T = 245 hrs.

$31.6 \leq \text{MTBI} \leq 299.7$

Iso- Reliability Relationship Between LAB and APG

Point Estimate k = 306

or, one hour of LAB is equivalent to 306 miles of APG testing.

81% Confidence Limits

$51.5 \leq k \leq 1371$

Major Incidents

APG

Number of Incidents = 28

MMBI = 10,714

90% Confidence Limits

$\chi^2_{.05,58} = 76.7716$

$\chi^2_{.95,56} = 39.802$

T = 300,000 mi.

$7815 \leq \text{MMBI} \leq 15{,}075$

LAB

Number of Incidents = 10

MTBI = 24.5

90% Confidence Limits

$\chi^2_{.05,22} = 33.924$

$\chi^2_{.95,20} = 10.851$

T = 245 hrs.

$14.4 \leq \text{MTBI} \leq 45.2$

Iso - Reliability Relationship Between LAB and APG

k= 437.3

81% Confidence Limits

$172.9 \leq k \leq 1046.9$

Minor Incidents

APG

Number of Incidents = 44

MMBI = 6818

90% Confidence Limits

$\chi^2_{.05,90} = 113.145$

$\chi^2_{.95,88} = 67.374$

T = 300,000 mi.

$5303 \leq \text{MMBI} \leq 8906$

LAB

Number of Incidents = 3

MTBI = 81.7

90% Confidence Limits

$\chi^2_{.05,8} = 15.507$

$\chi^2_{.95,6} = 1.635$

T = 245 hrs.

$31.6 \leq \text{MTBI} \leq 299.7$

Iso-Reliability Relationship Between LAB and APG

k = 83.5

81% Confidence Limits

$17.7 \leq k \leq 281.8$

APPENDIX A

ORIGINAL DATA

DEFICIENCIES & SHORTCOMINGS (INCIDENTS)
XM705 LABORATORY SIMULATION TEST

LAB TEST HOURS	DESCRIPTION
19.17	Right rear spring clip (front).
45.92	Rear motor mount cross member bolt broken.
58.17	Left front shock absorber rod broke (nut may have come out first causing rod to overextend).
62.00	Left front shock absorber mounting bolts loose (both main bolts).
72.58	Fatique cracks in both rear wheel housing flanges which bolt to cargo bed.
72.58	One bolt missing in right rear wheel housing.
73.58	Right rear shock absorber began to leak.
84.25	Slight fuel tank cap leak.
91.00	Front hold down bolts between cab frame and main frame under radiator loose and fell off. Also rubber mounts (2 each bolts and mounts, one assembly). (Replaced at 104.00 hours.)
91.30	Rear motor mount cross member bolts broke (2 bolts.)
107.58	Rear most fuel tank bracket cracked at 3 of 4 mounting holes.
112.83	Replaced 3 bolts that came out of rear motor mount cross member.

LAB TEST HOUR	DESCRIPTION
127.00	Broken left rear main spring leaf in front of U-Bolt.
141.92	Broken bolt in left rear wheel housing.
152.58	Crack in right bracket which mounts rear motor mount cross member to frame.
156.42	Front axle broke outboard of left shock absorber mount.
164.67	Frontmost fuel tank bracket cracked, one crack in top front mounting bolt.
195.83	Right rear spring clip, rear clip, loose and out of position.
213.50	Right rear spring mounting bolt hole elongated at front end of spring.
215.92	Left rear main spring leaf eyelet broken (front eyelet).
245.00	End of Laboratory Test.

INCIDENTS ATTRIBUTED TO VIBRATION
IN FIELD TESTS OF THE
XM705 AT ABERDEEN PROVING GROUND

Veh No.	EPR No.	Miles to Failure
Group 01: Engine		
1. Description: Both rear engine mounts loose and worn		
33771	937 X	42,675
33771	1120 X	14,325
33971	1090 X	22,275
34071	824 X	36,000
34071	1067 X	15,000
34171	801 X	30,450
34171	906 X	5,541
34171	1082 X	15,575
2. Description: Left rear lower engine mount worn/loose		
33971	799 X	31,725
33971	1163 X	27,483
3. Description: Right rear engine mount bolt broke		
33971	1150 X	26,475
Group 03: Fuel System		
4. Description: Fuel Tank center support strap, threaded end portion fractured		
33771	386	16,994
34071	761	32,135
34071	224	8,175
34171	215	7,725
Group 4: Exhaust System		
5. Description: Bolt crossover pipe to exhaust pipe assembly missing, broken, or loose		
34071	366 X	14,475
34071	1005 X	33,975
34071	1113 X	6,633
34171	393 X	17,100

Veh No.	EPR No.	Miles to Failure

Group 08: Transfer Assembly

6. Description: Transfer assembly support nuts securing the transfer case mounting brackets to frame cross member loose/missing

33971	32 X	1,230
34071	33 X	1,023
34171	34 X	958
34271	35 X	600
34371	36 X	1,009
33771	28 X	998
34171	45 X	715
33971	127 X	1,371
~~41571~~	~~133~~	~~225~~
34071	38 X	367
34171	964 X	42,000

Group 10: Front Axle Assembly

7. Description: Right front axle shaft and joint assembly broke, attributed to fatigue

34171	1169	59,032

Group 15: Frame and Hardware

8. Description: Mount: Subframe, front. Entire mount missing, consisting of one upper cushion, one lower cushion, two spacers, and two bolts.

33771	992	41,005
34071	322	13,950
34171	139	5,154
34271	140	4,650
34371	388	14,274
34071	970	8,471

9. Description: Subframe mounting bolts missing, loose, or broken

33771	852	15,675
34071	842	16,575
33771	994	5,345
33771	994	75
34371	110	3,000
34171	1076	51,000

Veh No	EPR No	Miles to Failure
34171	163	6,000
34071	175	6,000
33771	1001	9,975
33771	806	33,900
33771	929	8,100
33771	854	36,675
33971	390	16,686

10. Description: Frame crack across upper flange of right frame rail behind rear engine mount crossmember.

34171	1166	58,583

11. Description: Frame crack: Rear engine support crossmember cracked through three of the four upper mounting bolt holes.

34171	1083	51,750

Group 16: Springs and Shock Absorbers

12. Description: Rivets loose which secure shock absorber mounting bracket to frame rail.

33771	676	27,000	(left rear shock)
34071	486	21,000	(LR)
34271	501	21,000	(LR)
33771	529	21,000	(RR)
33971	913	39,000	(RR)
34071	977	48,000	(RR)
33771	529	21,000	(RF)
33971	814	33,000	(RF)
34071	762	32,125	(RF)
34171	995	43,275	(RF)
34171	501	21,000	(unspecified)

13. Description: Rivet loose or missing on alignment clip of Leaf Spring.

33771	405	18,000	Left rear
33971	151	6,000	spring, forward clip
34071	174	6,000	
34071	365	9,000	
34171	75	3,000	
34271	431	18,000	
34271	598	3,000	

33771	783	33,000	Left rear
33971	579	24,000	spring, rear clip
33971	757	6,000	

Veh No	EPR No	Miles to Failure	
34071	976	48,000	
34171	160	6,000	
34171	684	21,000	
34271	372	15,000	
34171	1143	15,966	
33771	530	21,000	Right rear
33771	783	12,000	spring, forward clip
34071	253	9,000	
33771	675	27,000	Right rear
33771	1059	24,000	spring, rear clip
34071	253	9,000	
34071	419	9,000	
34171	423	18,000	
34171	498	3,000	
34171	1048	6,966	

14. Description: Shock Absorber borken (Piston shaft inside broken)

34071	367	15,300	(LR shock)

15. Description: Shock Absorber malfunctioning. (poor damping)

33771	1070	39,375	(RF shock)

16. Description: Shock absorber leaking

33771	613	24,000	(LF)
33971	987	45,000	(LF)
33771	287	3,000	(RF)
34071	919	42,000	(RF)
33771	613	24,000	(LR)

17. Description: Upper Shock Absorber mounting nut loose

33971	373	15,375	(LF)

18. Description: Leaf Spring, main leaf fractured at curl.

33771	1029	49,800	(LR)

19. Description: Leaf Spring, main leaf broken two inches forward of rear spring mounts

33971	886	36,675	(LR)
34171	957	41,034	(LR)
34171	957	41,034	(RR)

Veh No	EPR No	Miles to failure	

20. Description: Leaf Spring. Main leaf broken just forward of rear spring hanger loop.

34071	1087	53,809	(LR)
33771	1084	53,475	(RR)
34071	1102	54,750	(RR)
34071	1116	31,125	(RR)

21. Description: Leaf Spring. Main leaf fractured at center of leaf across the bolt hole. Attributed to fatigue

33971	1159	22,350	(RR)

22. Description: Leaf Spring. Main leaf fractured at forward end where it forms loop around spring mount bushing.

34171	835	33,000	(LF)
34071	1134	57,825	(LF)

Group 18: Body, Cab, Hood

23. Description: Cab mount bolt loose

33771	804	33,900	(LR)
34071	1126	57,000	(LR)
34171	257	9,675	(LR)
34271	180	5,325	(LR)
34371	183	6,150	(LR)
33771	804	33,900	(RR)
34071	274	9,600	(RR)
34171	257	9,675	(RR)
34171	1007	43,500	(RR)
34271	180	5,325	(RR)
34371	186	6,300	(RR)
34371	567	14,700	(RR)

24. Description: Latch assembly, Tailgate. Tab broken from cargo body through weld. Attributed to bouncing of the load and vibration.

33771	403 X	18,000	(Left tab)
33971	582 X	24,000	
34071	811 X	35,175	
34071	950 X	10,608	
34171	502 X	21,000	
34171	683 X	27,000	
34171	1031 X	19,500	
34271	597 X	24,000	
34371	458 X	18,000	

Veh No	EPR No	Miles to failure	
33771	614X	24,000	(Right tab)
33771	1154X	35,327	
33771	1154X	24,000	
33971	582X	24,000	
34071	593X	24,000	
34071	811X	11,175	
34171	502X	21,000	
34171	606X	24,000	
34171	1031X	25,500	
34271	515X	21,000	

25. Description: Four bolts at rear of each rear wheel housing of the cargo body were very loose, requiring approximately three turns each to tighten.

33771	853	36,675

26. Description: Two small cracks in both rear corners of cargo body. Not serious enough to warrent repairs.

34371	458	18,000

27. Description: Minor cracks in both rear fenders. Cracks also detected at both rear corners of cargo body adjacent to rear bow sockets.

34371	559	21,000

APPENDIX B

INCIDENT MATCHING

INCIDENT MATCHING

Group 10: Front Axle Assembly

1. Description: Axle Broke.

	APG			LAB
341		EPR 1169	59,032 mi.	156 hr. 25 min.

Group 15: Frame and Hardware

2. Description: Front hold down bolts and rubber mounts between cab frame and main frame fell off.

	APG			LAB
342		EPR 140	4, 650 mi.	91 hrs
341		139	5,154	
340		970	8,471	
340		322	13,950	
343		388	14,274	
337		992	41,005	

3. Description: Mounting-bolts missing, loose, or broken (subframe).

	APG			LAB
337		EPR 852	15,675 mi	Not periodically
340		842	16,575	checked in lab.
337		994	5,345	Therefore excluded
337		994	75	in further analysis
343		110	3,000	
341		1076	51,000	
341		163	6,000	
340		175	6,000	
337		1001	9,975	
337		806	33,900	
337		929	8,100	
337		854	36,675	
339		390	16,686	

4. Description: Rear motor mount cross member bolts broken.

APG	LAB
	91 hr. 30 min.
	112 hr. 50 min.

5. Description: Rear Engine support cross member cracked.

	APG		LAB
341	EPR 1083	51,750 mi	152 hr. 35 min.

6. Description: Frame crack in main rail.

	APG		LAB
341	EPR 1166	58,583 mi	

Group 16: Springs and Shock Absorbers

7. Description: Rivets loose or missing on alignment clips of rear leaf springs.

	APG		LAB
337	EPR 405	18,000 mi	19 hr. 10 min.
339	151	6,000	195 hr. 50 min.
340	174	6,000	
340	365	9,000	
341	431	18,000	
341	75	3,000	
342	598	3,000	
337	783	33,000	
339	579	24,000	
339	757	6,000	
340	976	48,000	
341	160	6,000	
341	684	21,000	
342	372	15,000	
341	1143	15,966	
337	530	21,000	
337	783	12,000	
340	253	9,000	
337	675	27,000	
337	1059	24,000	
340	253	9,000	
340	419	9,000	
341	423	18,000	
341	498	3,000	
341	1048	6,966	

8. Description: Rivets loose which secure shock absorber to frame rail.

	APG		LAB
337	EPR 676	27,000 mi.	
340	486	21,000	
342	501	21,000	
337	529	21,000	
339	913	39,000	
340	977	48,000	
337	529	21,000	
339	814	33,000	
340	762	32,125	
341	995	43,275	
341	501	21,000	

9. Description: Shock absorber failure.

	APG		LAB
337	EPR 613	24,000 mi.	58 hr. 10 min.
339	987	45,000	73 hr. 35 min.
337	287	3,000	
340	919	42,000	
337	613	24,000	
337	1070	39,376	
340	367	15,300	

10. Description: Shock absorber mounting bolts loose.

	APG		LAB
339	EPR 373	15,375 mi	62 hr.

11. Description: Rear spring (main leaf) fractured due to abrasion.

	APG		LAB
337	EPR 1029	49,800 mi	215 hr. 55 min.
340	1007	53,809	
337	1087	53,475	
340	1102	54,750	
340	1116	31,125	
339	886	36,675	
341	957	41,034	
339	886	36,675	

12. Description: Broken main leaf at center due to fatigue.

	APG		LAB
339	EPR 1159	22,350 mi	127 hr.

13. Description: Front spring (main leaf) broken at curl.

	APG		LAB
341	EPR 835	33,000 mi	
340	1134	57,825	

Group 18: Body, Cab, Hood

14. Description: Cab Mounting bolts loose

	APG		LAB
337	EPR 804	33,900 mi.	
340	1126	57,000	
341	257	9,675	
342	180	5,325	
343	183	6,150	
337	804	33,900	
340	274	9,600	
341	257	9,675	
341	1007	43,500	
342	180	5,325	
343	186	6,300	
343	567	14,700	

15. Description: Fuel tank support straps failed.

	APG		LAB
337	EPR 386	16,994 mi	107 hr. 35 min.
340	224	8,175	164 hr. 40 min.
340	761	32,135	
341	215	7,725	

16. Description: Cracks in wheel housing

	APG		LAB
343	EPR 559	21,000 mi	72 hr. 35 min.

17. Description: Bolts loose, broken, or missing-rear wheel housing.

	APG			LAB
337		EPR 853	36,675 mi.	72 hr. 35 min.
337		EPR 853	36,675 mi.	

18. Description: Cracks in both rear corners of cargo body.

	APG			LAB
343		EPR 485	18,000 mi.	

APPENDIX C

OVERALL INCIDENT SUMMARY

OVERALL INCIDENT SUMMARY

Incident No.		Incident Description	APG	LAB
1.*	G 10:	Axle Broke	1	1
2.	G 15:	Front hold down bolts & rubber mounts broke & fell off	6	1
3.**	G 15:	Mounting bolts missing, loose, or broken (subframe).	13	0
4.	G 15:	Rear motor mount cross member bolts broken.	0	2
5.	G 15:	Rear engine support cross member cracked	1	1
6.	G 15:	Frame crack in main rail	1	0
7.	G 16:	Rear spring rivets and clips	25	2
8.	G 16:	Shock absorber rivets to frame	11	0
9.	G 16:	Shock absorber failure	7	2
10.	G 16:	Shock absorber mounting bolts loose	1	1
11.	G 16:	Rear spring main leaf failure due to abrasion	8	1
12.	G 16:	Rear spring main leaf failure at center	1	1
13.	G 16:	Front spring failure at curl	2	0
14.	G 18:	Cab mounting bolts loose	12	0
15.	G 18:	Fuel tank support strap broke	4	2

*Incident Numbers refer to Appendix B.

** Not periodically checked in lab.

16.	G 18:	Crack in wheel housing	1	1
17.	G 18:	Bolts loose, broke, missing in rear wheel housing	2	1
18.	G 18:	Cracks in both corners of cargo body	1	0

APPENDIX D

INCIDENT CATEGORIZATION

INCIDENT CATEGORIZATION

CATASTROPIC INCIDENTS

INCIDENT NO.	APG	LAB
1	1	1
11	8	1
12	1	1
13	2	0
TOTAL	12	3
MMBI/MTBI	30,000 mi.	81.7 hr.

MAJOR INCIDENTS	APG	LAB
4	0	2
5	1	1
6	1	0
8	11	0
9	7	2
10	1	1
15	4	2
16	1	1
17	2	1
TOTAL	28	10
MMBI/MTBI	12,857 mi.	24.5 hr.

MINOR INCIDENTS		APG	LAB
2		6	1
7		25	2
14		12	0
18		1	0
	TOTAL	44	3

MMBI/MTBI	8,182 mi.	81.7 hr.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Test Management Branch (AMSTA-RHT)
Concept and Technology Division
US Army Tank-Automotive Command, Warren, Mi., 48090

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

CORRELATION STUDY ON A 1¼-TON TRUCK BETWEEN FIELD TESTS AT ABERDEEN PROVING GROUND AND LABORATORY SIMULATION TEST AT TACOM

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

CAROL D. ROSE

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 1974	41	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
1G765702D063	11865
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

Purpose of this study was to determine the degree of correlation of vibration-induced failure incidents between field tests at Aberdeen Proving Ground (APG) and a laboratory simulation test of the 1¼-Ton XM705 Truck.

Six trucks were field tested at APG. A total of 300,000 test miles were accumulated. An accelerated laboratory simulation test was developed from operating field data recorded on magnetic tape at APG. A 245-hour laboratory vehicle shake test was run on one vehicle. A study was made to determine the degree of correlation between the field tests and laboratory test.

Field tests produced 17 types of failure mode incidents attributed to vibration. The laboratory produced 11 (64.7 percent) of the same failure mode incidents. Mean miles between incidents in the field test was 3,571. Mean time between incidents in the laboratory was 15.31 hours. Based on an iso-reliability relationship, one hour of laboratory testing was equivalent to 233.2 miles of field testing.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Simulation Test						
Laboratory Simulation						
Accelerated Laboratory Test						
Correlation Between Field and Laboratory Tests						
Vehicle Shake Test						